Contrast Discrimination Can Explain

Orientation Discrimination

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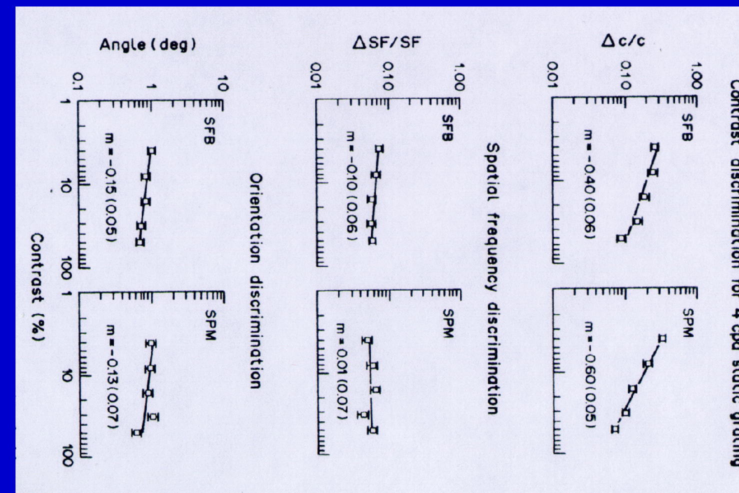
The Problem



(from S.F. Bowne, *Vision Research* 1990;30(3):449-461)

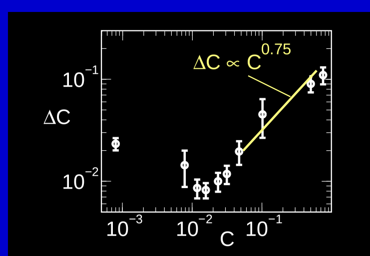
The Problem

Relative increment contrast discrimination thresholds improve with contrast:

Weber's (or Guilford's) law

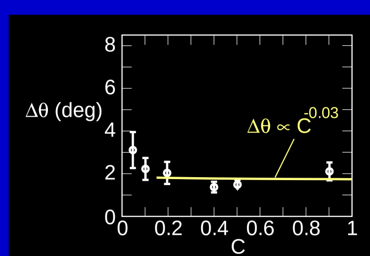
$\Delta C \propto C^{0.7}$

$\Delta C / C \propto C^{-0.3}$

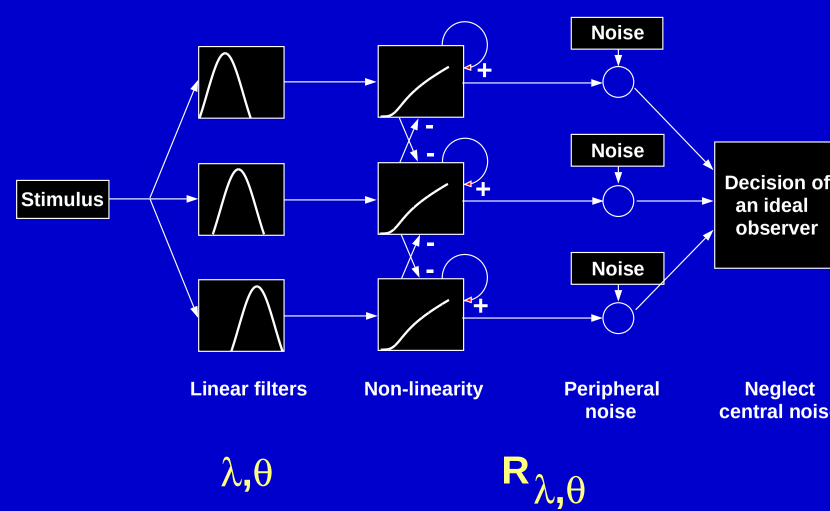


But orientation discrimination thresholds do not

$\Delta\theta \propto C^{-0.1} \approx$ const.



Typical Model of Early Vision



Psychophysical Decision

Discriminate between stimulus A and B by comparing the filter responses:

R^A and R^B

i.e., thresholds are functions of response differences:

$\Delta C \propto f_C(\Delta R)$ $\Delta\theta \propto f_\theta(\Delta R)$

Hence: $\Delta\theta \propto C^0 \Rightarrow \Delta R \propto C^0$

$\Delta C \propto C^{0.7} \Rightarrow$ ~~$\Delta R \propto C^0$~~

The Solution?

Discriminate between stimulus A and B by comparing the filter responses:

R^A and R^B

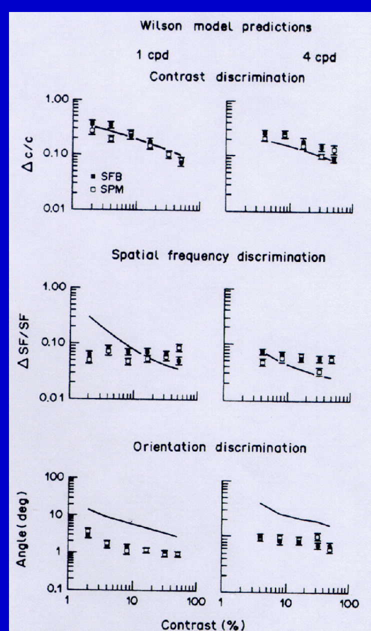
i.e., thresholds are functions of response differences:

$\Delta C \propto f_C(\Delta R)$ $\Delta\theta \propto f_\theta(\Delta R)$

But:

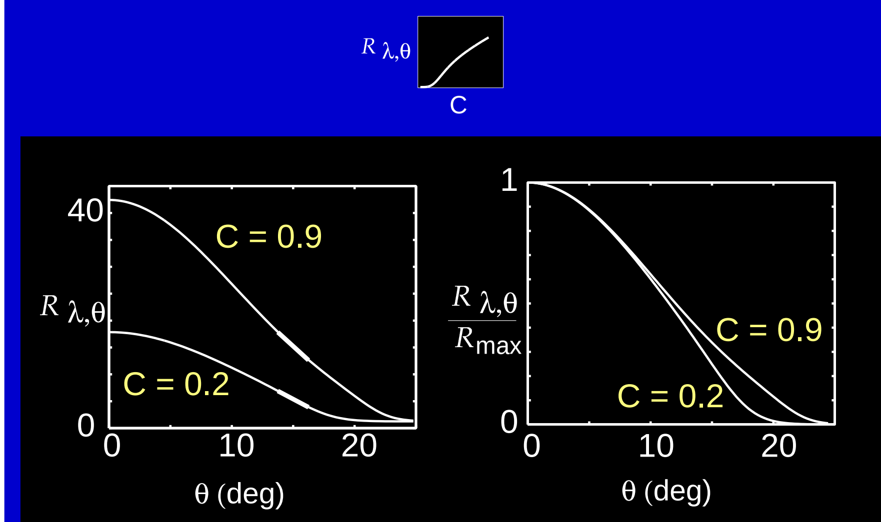
f_θ depends on C!

Consequence for Vision Models



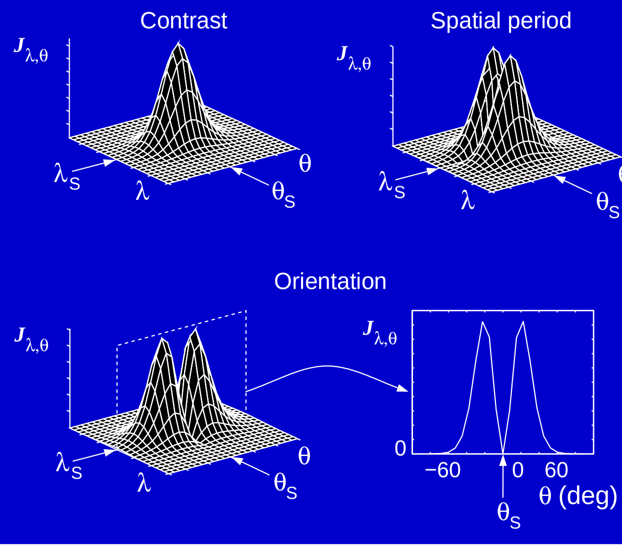
They don't work!

f_θ depends on C

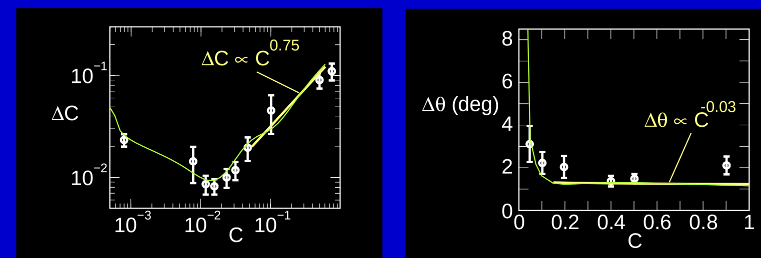


Slope of orientation tuning curve becomes shallower with C

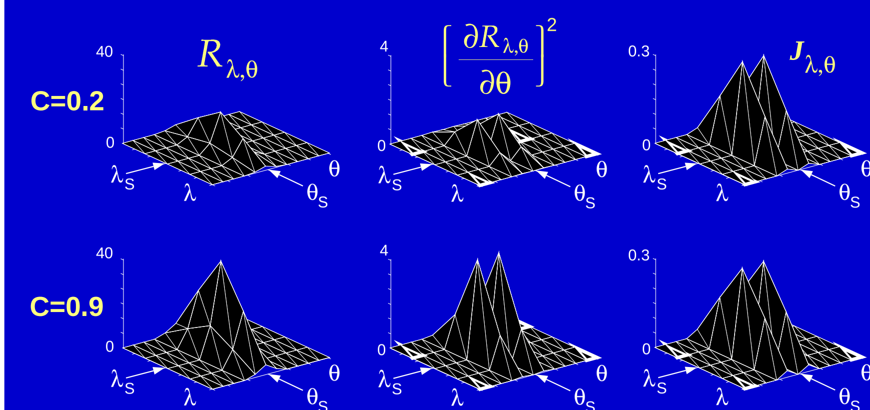
And the region where f_θ depends most on C is the most informative



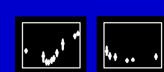
Model Simultaneously Fits Contrast and Orientation data



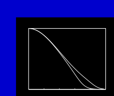
Fisher Information: $J_{\lambda,\theta} \approx \left[\frac{\partial R_{\lambda,\theta}}{\partial \theta}\right]^2 \Big/ R_{\lambda,\theta}$



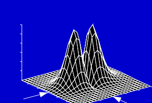
Summary



Improvement in ΔC/C with C suggests that neuronal responses increase with C, but lack of improvement in Δθ suggests they do not

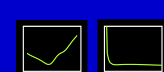


However, when response is sigmoidal in C, effective tuning curves become shallower with C



This reduces Fisher information because it reduces ∂R/∂θ

Most affected are the neurons which are most informative about stimulus orientation



Net effect: contrast-dependent change of tuning counteracts increase in response

1999 Research Portfolio

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